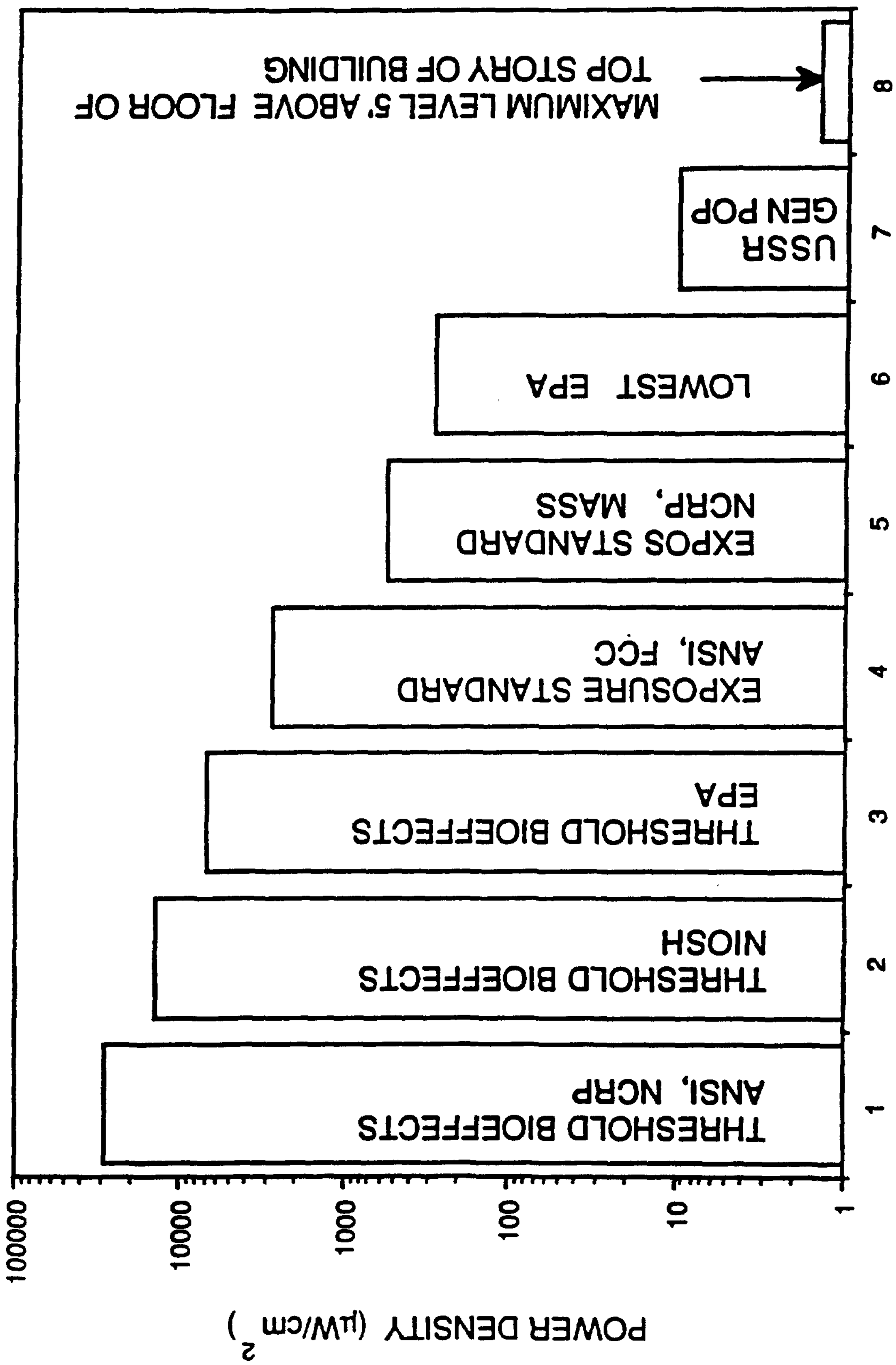

Figure 2. Comparison of maximum radiation levels inside building for roof mounted cellular telephone antenna with Exposure Standards.

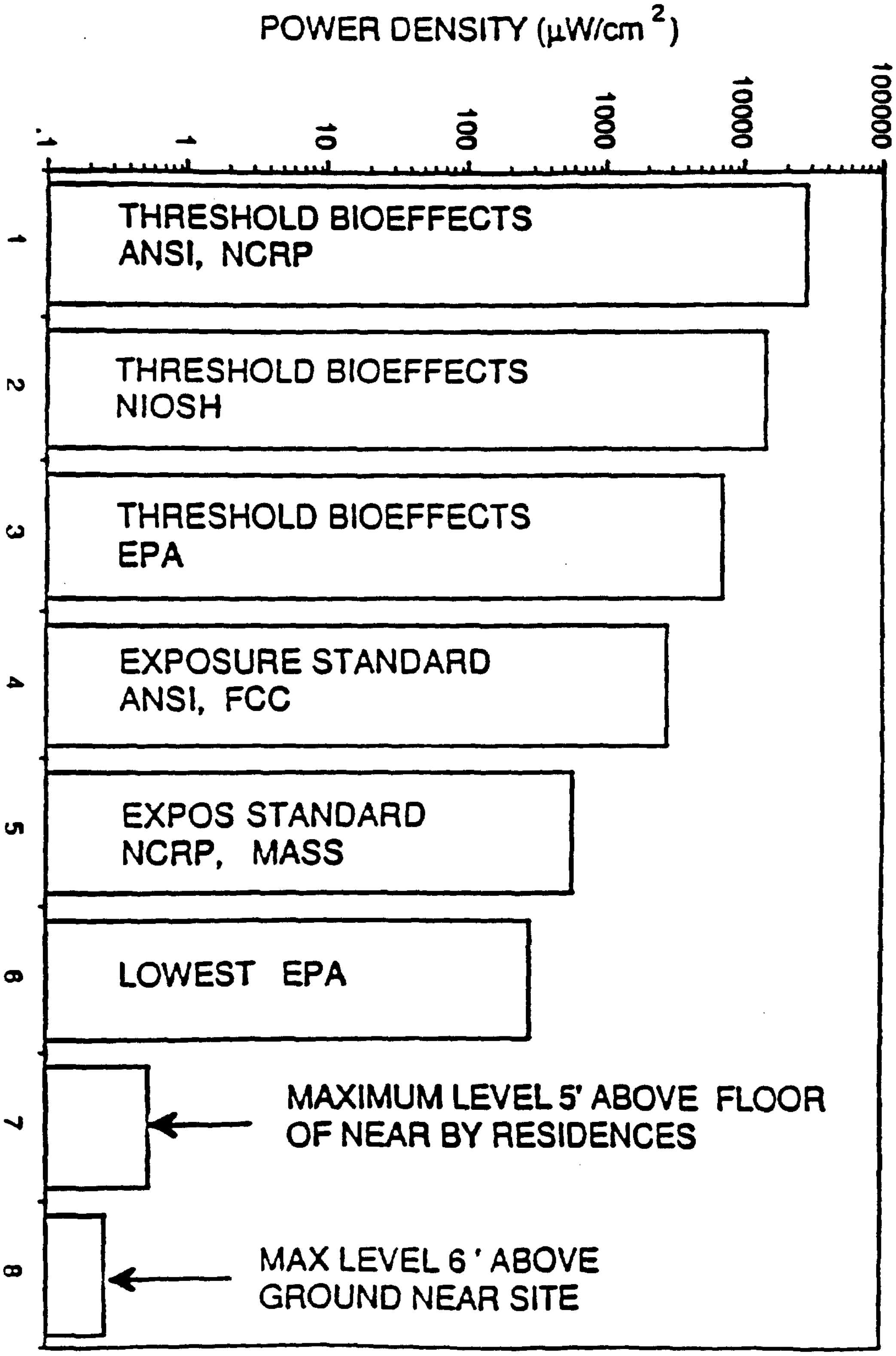

Figure 3. Comparison of tower mounted cellular telephone radiation levels with USA Standards.

TAB F

Om P. Gandhi 8/2/93

ELECTROMAGNETIC ABSORPTION IN THE HUMAN HEAD FOR CELLULAR TELEPHONES

Summary

We have used both computational and experimental techniques to obtain mass-normalized rates of electromagnetic energy absorption (specific absorption rates or SARs) in the human head for ten cellular telephones from four different manufacturers. For numerical computations we have used a newly developed high-resolution model of the human body that was obtained from the magnetic resonance imaging (MRI) scans of a male volunteer. For this model, anatomically based tissue properties were prescribed for each of the subvolumes or "cells" of dimensions approximately $2 \times 2 \times 3$ mm or 11.7 milligrams of the tissues. The well-established finite-difference time-domain computational technique was used to calculate the electromagnetic fields and SARs for all the regions of the body with particular emphasis on head, neck, shoulders, and the upper torso for cellular phones held against the ears. Because of the proximity of the upper ear to the radiating antenna, most of the electromagnetic absorption occurs for the upper cartilage-dominated part of the ear with a rapidly diminishing SAR for the nearby tissues in the head. For the tissues in the head, the SARs diminish rapidly to 1 percent of the peak SAR values for the upper ear at a depth of 3-5 cm from the side of the head against which the phone is held, and are relatively miniscule elsewhere.

We have verified the highlights of the numerical calculations by means of a head-shaped experimental model made of tissue-equivalent materials simulating the electromagnetic properties (dielectric constant and electrical conductivity) of skull, brain, muscle, eyes, and ears developed for use at the cellular telephone frequency of 835 MHz. For this heterogeneous model, the SARs were obtained experimentally by measuring the radio frequency electric fields that were created by each of the telephones.

Based on the detailed studies of these telephones, the highlights of the results are as follows:

1. For a maximum possible antenna power of 600 mW, the power absorbed by the head and neck, depending on the telephone and the nature of its antenna, can vary from 23 to 65 mW. The power absorbed by the whole body is not much higher and can vary from 33 to 78 mW.
2. The peak SAR averaged over any 1 g of tissue defined as a volume in the shape of a cube occurs for the volume involving the upper ear. The peak 1 g SAR is on the order of 0.09 to 0.29 W/kg, depending on the telephone and the nature of its antenna. This is considerably smaller than the 1.6 W/kg suggested in the ANSI/IEEE C95.1-1992 safety guidelines. If the 1 g of tissue in the form of a cube is all taken to be the inside tissue such as for the brain, the peak 1 g SAR is even smaller. For the various telephones we have found the peak values of the SARs for any 1 g of tissue, all in the brain, to be between 0.04 to 0.17 W/kg.
3. The whole-body-average SAR can be obtained by dividing the total power absorbed by the weight of the body. For total-body absorbed powers on the order of 33 to 78 mW, a whole-body-average SAR on the order of 0.5 to 1.1 mW/kg is obtained. Once again, this is a factor of 80 to 160 times smaller than the whole-body-average SAR of 0.08 W/kg or 80 mW/kg considered to be acceptable by the ANSI-1992 safety standard.

Another factor to be considered is the averaging time of 30 minutes prescribed in the ANSI safety guideline at the cellular telephone frequency of 820-850 MHz. The time-averaged values of the whole-body-average and spatial-peak SARs would, therefore, be smaller than the above quoted values if the cellular telephone is in operation for only a fraction of time in any given 30-minute period.